CIRCULAR SERIES

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WOOD FRAMING

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SMALL HOMES COUNCIL F3.0

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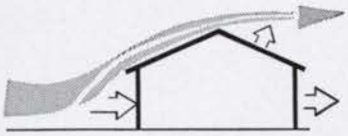
HOUSES MUST BE DESIGNED TO SUPPORT LOADS



Wind loads are horizontal loads.

The framework for a house must be strong enough to support various types of loads — snow and ice, wind, earthquake, occupants and furnishings, and the weight of the house itself. The severity of these loads depends on the geographic location of the house and the way the occupants use it.

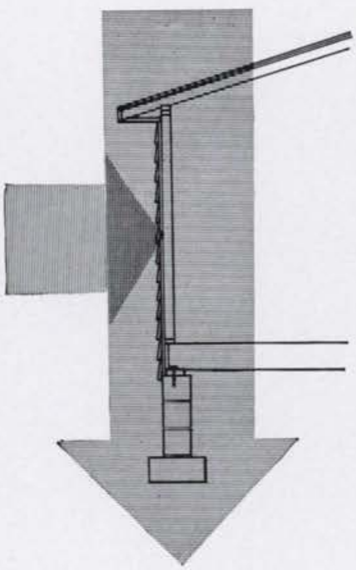
Loads caused by climatic conditions — wind, snow, and ice — are received first by the covering of the house (roofing, siding, sheathing). They are then transferred to the frame of the house (rafters, studs, joists), then to the foundation, and finally to the ground.

Wind loads are horizontal loads, their force being primarily against the walls of a house. They may also create pressure against the roof, either a lifting or a downward action.

Snow and ice loads are vertical loads carried by the roof. They exert pressure downward.

Loads due to occupants and furnishings are received first by the flooring since these loads start within the house and are primarily vertical loads. These loads and the weight of the structure itself are then transferred through the framing to the foundation and to the ground.

Earthquake loads, common only in limited areas, are generally horizontal loads originating in the ground. They result in foundation movement which is transferred upwards to the frame of the house.



A house must be strong enough to resist horizontal loads (wind) and vertical loads (snow, ice, occupants, furnishings, structural weight).

House Behavior Under Loads

Every structural member (piece) of a framing system responds to loading with either a very slight change in dimension or a slight amount of deflection (bending) — or both. For example:

- A horizontal member supporting a load — *i.e.,* a beam — will bend or sag.
- A vertical member supporting a load — *i.e.,* a post or stud — will compress or shorten, and may even bend slightly.
- A vertical member from which a load is hung — *i.e.,* a hanger — will stretch or lengthen.

If it is known how each part of a framing system behaves under load, the required stiffness and strength for each member can be established — that is, the size of the lumber needed to give the necessary support without noticeable distortion. The amount of movement allowable for each member varies with its function, its location, and the type of covering materials on the house.

The response of each individual member to loading is passed on to the completed building. This transferal causes a slight amount of movement in the roof, ceiling, wall, floor, and foundation construction since all these structural parts are connected one with another. These movements are normal and are of no concern to the homeowner unless the loads make the movements so pronounced that they 1) are noticeable and objectionable; 2) cause cracking or separation of materials at the joints; 3) cause improper functioning of other elements in the house, such as doors sticking; or 4) indicate possible collapse of the structure. The first three conditions can be caused by changes in the moisture content of wood (and other building materials), as well as by loads.

Resistance of House to Loads: A completed house acts as a whole in resisting loads. The floor, exterior walls, partitions, and roof give support to one another and, thus, provide an over-all stiffness and stability to the structure.

To avoid severe structural movement and to obtain stiffness and stability, the connections must be relatively rigid between 1) the covering material and the framing; 2) the principal structural members; 3) the major parts of the building; and 4) the building and the foundation.

Foundations: All framing systems need foundations that are adequate to hold, without excessive settling, the loads imposed on them. To prevent the house from turning, sliding, or being lifted from its foundation under severe wind loads, anchor bolts should be used to connect the framing and the foundation.

Lumber and Construction

The exact size, spacing, and grade of lumber* required to give each framing member its necessary strength and stiffness are engineering problems, and should be determined by an architect, engineer, or builder who is qualified. A guide for selection of lumber grades for various framing uses is given in SHC – BRC Circular *D7.0, Selecting Lumber.*

The best assurance of uniform quality and adequate inspection is the mill stamp which is placed on the lumber. Use of "green" or unseasoned lumber is not recommended since it presents more problems than lumber which has been dried (maximum moisture content of 19 per cent). Moisture changes during seasoning usually cause lumber to shrink, thus affecting the width and thickness of each piece. Buildings should be framed so that the shrinkage will be equal at each major support.

Carefully drafted working drawings, details, specifications, and supervision all help to insure compliance with the structural requirements. The common sense and judgment of workmen must be relied on to prevent use of an occasionally unsound piece, the severe splitting of nailed joints, and similar structural weaknesses. Patching or reinforcing of damaged or sub-standard structural members is rarely adequate; these should be replaced.

Since the load that a member can carry is proportional to the area of the member, notching and drilling should be kept at a minimum.

CHOICE OF FRAMING SYSTEMS

In addition to load factors, the choice of a framing system is influenced by: 1) architectural considerations — over-all shape, roof type, interior plan of the house, and appearance; 2) type, size, and location of door and window openings; 3) installation of insulation, vapor barrier, utility lines, and heating pipes or ducts; 4) requirements of local building codes; and 5) costs of construction (see page 7).

Design of House: The architectural design and structural design of a house are interrelated. Usually the simpler the over-all shape of the house, the simpler is the framing system. The most economical shape is the rectangle. Ells, bays, and recesses add to the complexity of framing to some degree, as do breaks in the plane of the roof and floor.

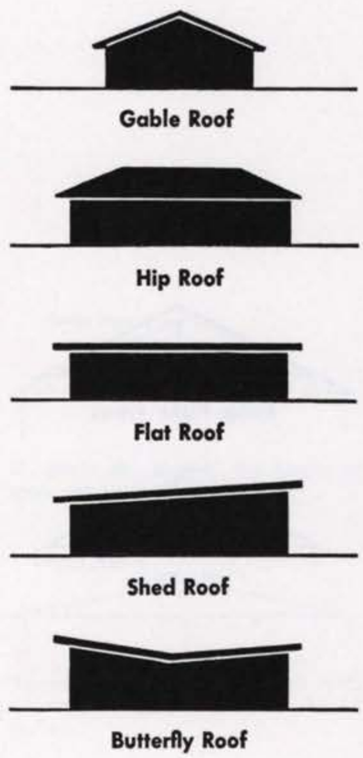
Framing systems that require load-bearing partitions to help support the roof place the most severe limitations on planning. Roof frames which span the entire width of the house make for greater freedom in planning and arranging the house interior and for greater flexibility in its use.

Window and Door Openings: Wall construction having windows and doors must be modified so that the framing around the opening is strong enough to carry all loads to the foundation.

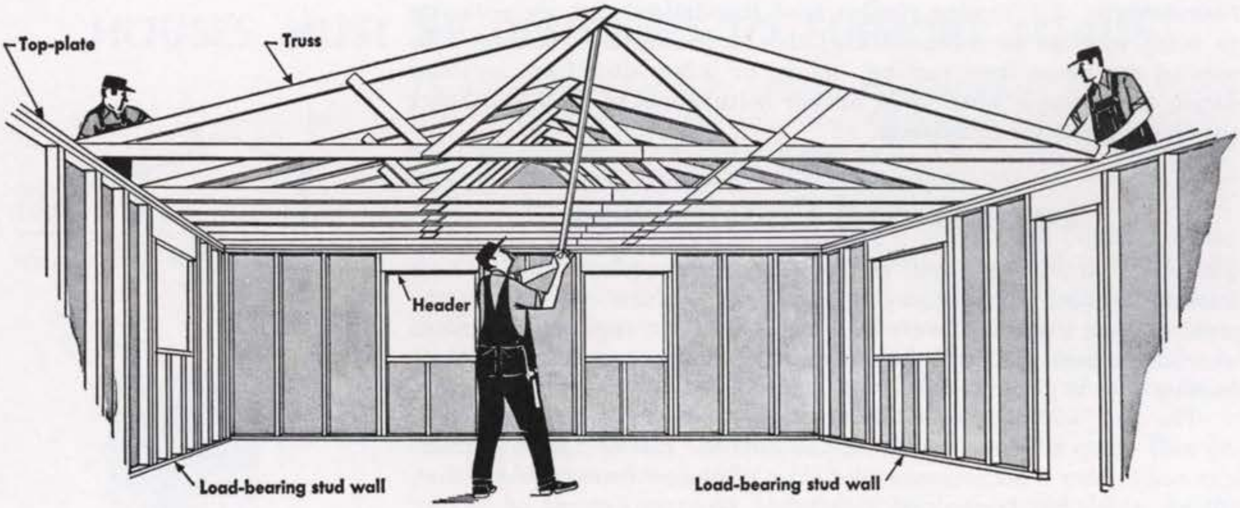
Framing Depth: The framing must be deep enough to accommodate insulation and also, in some cases, the passage of utility and heating lines. It must also provide a nailing base for coverings, insulation, vapor barrier and trim.

Building Codes: The wood framing systems described in this circular are the most common ones in use for houses today and are acceptable under most building codes.

ROOF PROFILES



* For general guidance in selection of members, see "Table of Maximum Allowable Spans," *Minimum Property Standards for One and Two Living Units,* Federal Housing Administration; and *Wood Structural Design Data,* National Lumber Manufacturers Association.



ROOF-TRUSS CONSTRUCTION

Roof trusses are triangular frames which rest on the exterior walls and span the entire width of the house. Because they relieve interior partitions of the weight of the roof, considerable freedom in the planning and division of space within the house is possible. The house, moreover, can be built as one open room, and finish material applied to walls, ceilings, and floor before partitions are erected. This reduces material and labor costs since the cutting and the fitting of materials are held to a minimum.

Trusses are pre-cut and assembled at ground level, and each truss is lifted into place as a unit. Such construction makes it possible to get the house under cover quickly.

Trusses can be placed at intervals of 1 to 8 feet along the length of the house, but the most common spacings are 16 inches and 24 inches. If spaced at 24 inches, trusses are the most economical construction for a gabled-roof house.

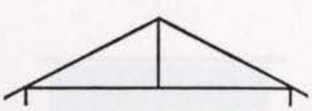
Trusses must be built from designs developed from engineering data, or else tested for strength and stiffness for their specific use. Truss designs for gable roofs are available from the Small Homes Council for both 1-story and 1½-story houses.*

Hip roofs can be framed through the use of special trusses or through combination of trussed and joist-and-rafter framing.

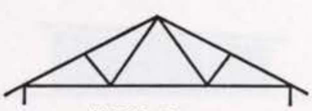
Trusses require heavier and more complex connections between members than conventional rafter-and-joist roof framing. Trusses should not be cut and patched at random, or notched to pass utilities.

Since the ceiling and the roof act as a unit under roof loads, trusses must be designed so that when they deflect under load, the ceiling material will not crack.

Insulation and vapor barriers are easily installed in truss construction.



King-Post Truss

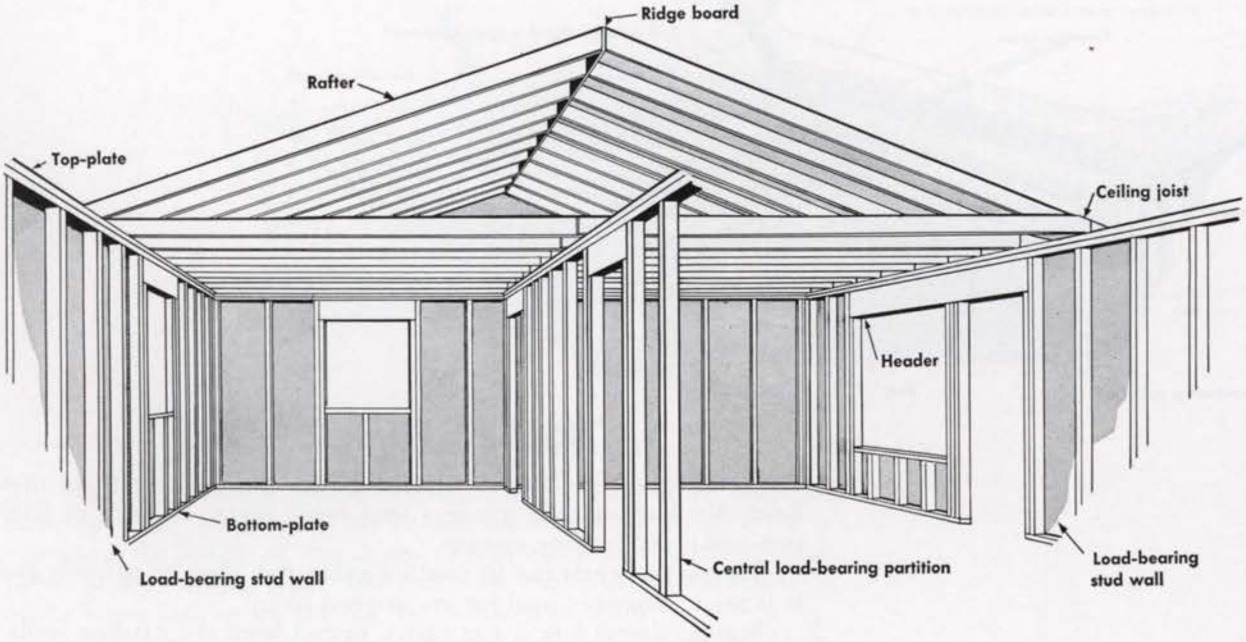


"W" Truss

* Instruction sheets available for 50 cents each are:

- #1 — NAIL-GLUING OF ROOF TRUSSES AND FRAMES (general technique)
- #2 — 2/12 NAIL-GLUED ROOF TRUSS, 20′-8″ to 28′-8″ Spans
- #3 — 3/12 NAIL-GLUED ROOF TRUSS, 20′-8″ to 28′-8″ Spans
- #4 — 4/12 NAIL-GLUED ROOF TRUSS, 20′-8″ to 28′-8″ Spans
- #5 — LONG-SPAN "W" NAIL-GLUED ROOF TRUSSES, 29′-0″ to 40′-8″ Spans; 2/12, 3/12, 4/12 Slopes
- #6 — 2″ x 4″ KING-POST NAIL-GLUED ROOF TRUSSES, 18′-0″ to 24′-8″ Spans; 2/12, 3/12, 4/12 Slopes
- #7 — 2″ x 6″ KING-POST NAIL-GLUED ROOF TRUSSES, 25′-0″ to 32′-8″ Spans; 2/12, 3/12, 4/12 Slopes
- #8 — SLOPED CEILING, PLYWOOD WEB ROOF-FRAMES, 21′-0″ to 32′-8″ Spans; 3/12 Roof Slopes, 1.5/12 Ceiling Slope
- #9 — PLYWOOD WEB ROOF-FRAME, 1/12 Slope; 20′-8″ to 28′-8″ Spans
- #10 — HIP-ROOF NAIL-GLUED TRUSSES, 21′-0″ to 28′-8″ Spans; 3/12 Roof Slope

TRUSSED ROOF-FRAME FOR 1½-STORY HOUSE (22′-8″ to 28′-8″ Spans; 8/12, 9/12 Slope)
3/12 SLOPE TRUSS FOR 20′-8″ to 30′-8″ Spans
"W" TRUSS FOR 20′-8″ to 32′-8″ SPANS (5/12 Slope, 2′ on center)



JOIST-AND-RAFTER CONSTRUCTION

In joist-and-rafter construction, ceiling joists extend from the exterior walls to a load-bearing partition which runs the length of the house. Rafters are supported at the eaves by the exterior walls. At the peak of the roof, the rafters bear against a non-structural ridge board which extends the length of the house. The ceiling joists, functioning as a tie, prevent the rafters from spreading. If rafters are braced, the length of span can be increased.

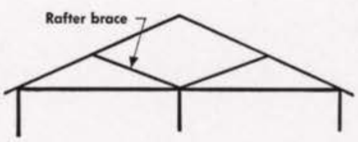
Joist-and-rafter construction can be used for gable and hip roofs, but it is usually limited by building codes to roofs sloping 5 or more inches in 12. For roofs of lesser slopes, construction should be modified by providing a vertical support at the peak of the roof framing. Joists and rafters are commonly spaced at 16 or 24 inches. The latter is the most economical spacing.

Joist-and-rafter construction is a universally acceptable framing system and is known to most workmen. Other advantages are:

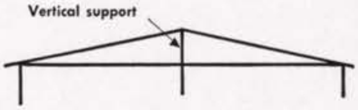
- Roof loads can be carried to the walls without causing ceiling deflection.
- Common types of sheathing and finish materials can be used.
- Insulation can be easily placed in the ceiling construction, and vapor barriers concealed by finish material.

Because of the bearing partition, this type of roof framing restricts flexibility in planning the interior of the house. Other disadvantages, as compared to truss construction, are:

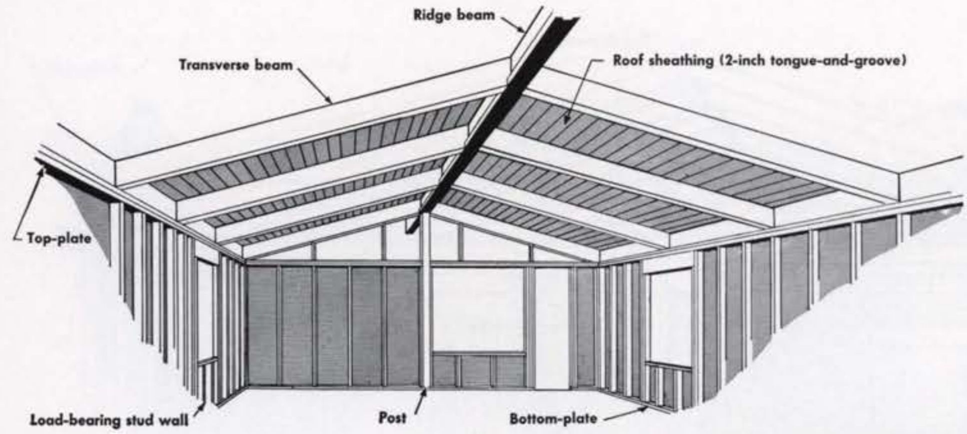
- A longer time is required for erection and, hence, there is longer exposure of material to weather.
- Roof framing must be accomplished by men who work "in the air," supported by either ceiling joists or scaffolding.



If rafters are braced, the length of span can be increased.



Vertical support is needed for roofs of slopes less than 5 inches in 12 inches.



TRANSVERSE BEAMS

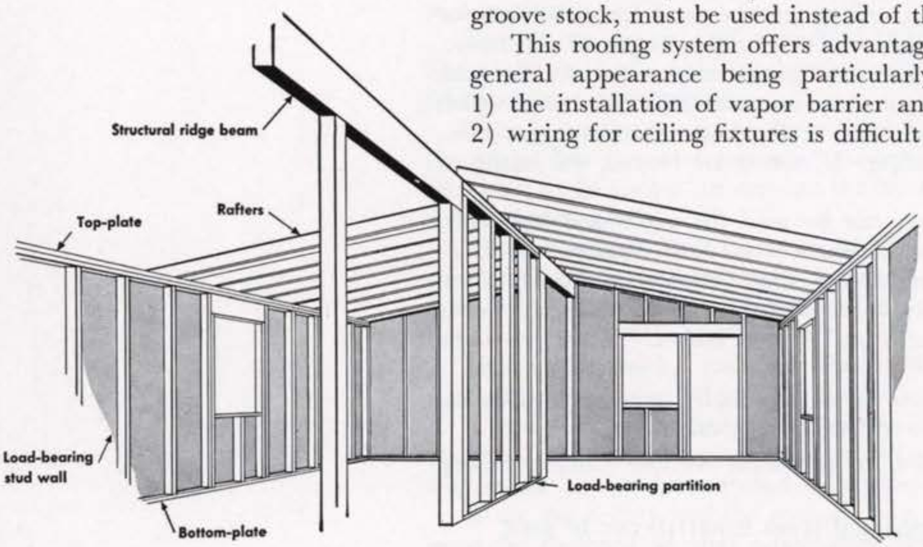
The transverse-beam system usually utilizes the roof sheathing as the finished-ceiling material, giving a semi-rustic effect. It is one of several post-and-beam framing systems.

Transverse beams can be used for gable, flat, shed, or butterfly roofs. It is most commonly used for low-pitched roofs.

Beams, placed 4 to 8 feet apart, extend from the exterior walls to the center of the house where they are supported by a ridge beam which runs the length of the house. The interior is free from obstructions except for the posts supporting the ridge beam. (A load-bearing wall can be used instead of a ridge beam.)

Because of the wide spacing of beams, 1) beams must be wider than 2 inches; and 2) heavy roof sheathing, such as 2-inch tongue-and-groove stock, must be used instead of the more common sheathings.

This roofing system offers advantages from a design standpoint, the general appearance being particularly pleasing. Disadvantages are: 1) the installation of vapor barrier and insulation is complicated; and 2) wiring for ceiling fixtures is difficult to conceal.



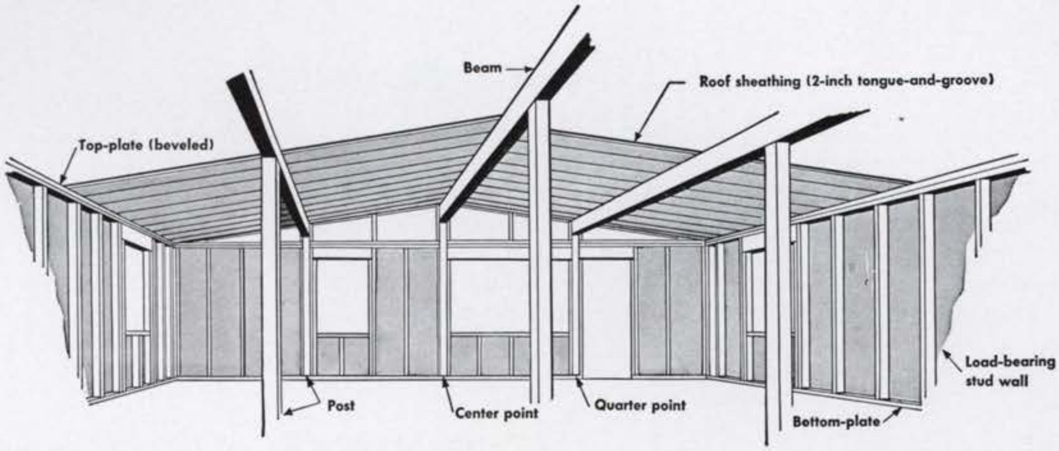
RAFTERS WITH RIDGE SUPPORT

A compromise between rafter-and-joist framing and transverse-beam framing is the use of rafters with ridge support. A load-bearing partition or structural ridge beam supports the peak of the roof framing which consists of rafters spaced 12 to 24 inches. The rafters span from the peak to the exterior walls and support the sheathing and the ceiling material.

This method of framing is suitable for gable, flat, shed, and butterfly roofs.

This system offers the same design advantages as the transverse-beam system. It has the following additional advantages:

- The closer spacing of the primary framing allows the use of 2-inch rafters, and common sheathing and ceiling materials.
- Ceiling finish-materials can be used, thus eliminating difficulties in installing utility lines, vapor barriers, and insulation.



LONGITUDINAL BEAMS

The longitudinal-beam system is suitable for gable, shed, flat, and butterfly roofs. Such roofs can be framed with three parallel beams extending the length of the house. These are placed at the quarter points of the building span. The beams are supported by the end-walls of the house and, on the interior, by partitions or posts.

Most commonly the tops of the beams are beveled or blocked to the roof slope. The exterior walls should be provided with a plate beveled to the roof slope.

The space between beams is spanned by the roof sheathing, usually 2-inch tongue-and-groove stock. The sheathing, which is also supported by the exterior walls, is laid perpendicular to the ridge line. Rafters and standard sheathings can be used instead of the 2-inch stock.

The longitudinal-beam system has the same advantages and disadvantages noted for transverse-beam framing. In addition, it has the following disadvantages:

- Planning of the interior space is more restricted due to the greater number of interior supports required.
- Beams, walls, and partitions parallel to the length of the house must have continuity since this system lacks the tying effect of sheathing laid parallel to the ridge.

COST

Framing costs are influenced by many variables. Research studies* have shown that:

- The most economical spacing for roof members is 24 inches. An increase in the spacing between the primary framing members (for example, spacing trusses 8 feet rather than 2 feet on center) reduces the square-foot cost of the bare framing. This saving, however, is quickly lost when the necessary coverings for the wider spacing are added due to the fact that heavier materials must be used for sheathing and ceiling. Where other considerations dictate the use of wider spacings, it is generally more economical to use subframing (purlins) and conventional covering materials.
- For a gable-roofed house, truss construction is more economical than rafter-and-joist construction.
- When the Small Homes Council's nail-glued roof trusses are used, a house width of 28 feet is the most economical span.
- The bare framing for a flat roof is cheaper than the economical nail-glued trusses; however, the increase in sheathing and roofing costs for flat roofs is more than enough to override the savings in the bare framing.

* Small Homes Council study on framing sponsored by the Housing and Home Finance Agency, *Material and Labor Analysis House Framing Systems*, HHFA Housing Research Paper 33, April 1954, 65 cents, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Small Homes Council's study 1957-58, "Effect of Span on Cost," John I. Zerbe, *13th Annual Short Course in Residential Construction*, $2.50, Small Homes Council, University of Illinois, Mumford House, Urbana, Illinois.

WALL FRAMING

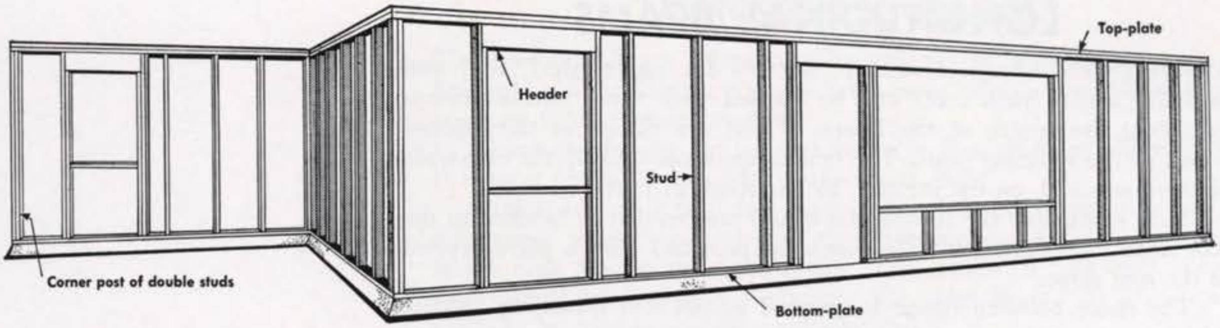
In most framing systems, the exterior walls must bear vertical loads (weight of roof, ice, snow, occupants, furnishings). Such walls are "load-bearing walls."

In other framing systems, the vertical loads are borne by posts. The exterior walls merely close in the structure and are referred to as "curtain walls."

Regardless of whether the exterior walls merely curtain the house or resist some of the vertical load as well, they must be stiff enough to withstand wind loads. The siding and sheathing must be strong enough to transfer these loads to the posts or studs.

Types of wall framing of wood, most commonly used in houses today, are stud walls (load-bearing) and post-and-panel walls (curtain walls).

STUD WALLS



Studs, vertical members usually of 2-inch lumber, are used in stud-wall construction to carry roof and ceiling loads. The studs extend from the bottom-plate to the top-plate.

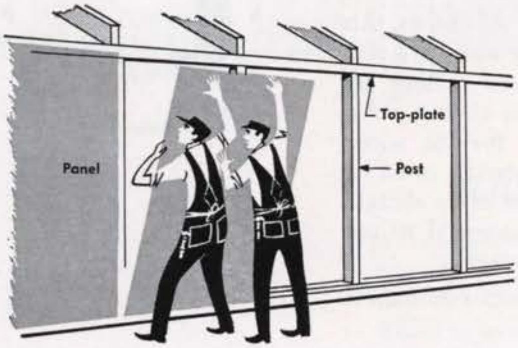
Studs are commonly spaced from 12 to 24 inches. When studs are spaced 24 inches, the stud wall is the most economical wall construction (If they are spaced farther than 24 inches, the economies are lost since covering materials must be heavier and, hence, more expensive.)

Sheathing and finish materials brace the studs which are, in themselves, too slender to function as columns under vertical loads.

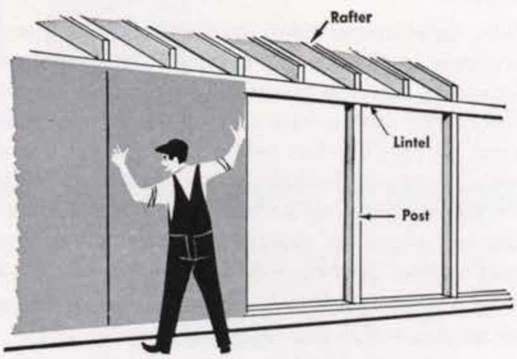
Stud walls, complete with sheathing and siding, can be assembled on the ground and tipped into place — a more efficient system than building walls "in the air." Stud walls can also be built in sections (pre-assembled panels) which are then assembled into walls at the site.

A recent development in stud wall framing is the use of a continuous header which replaces the double top-plate and the individual window headers.

POST-AND-PANEL WALLS



Posts are spaced the same as roof framing members.



Posts can be spaced independently of roof framing members.

Curtain-wall panels (either prefabricated or job-built) can be used to fill the openings between structural posts spaced 4 feet or more apart. These posts can be placed in two ways:

1. At the same spacing as the roof framing members which span the width of the building.
2. Independently of the roof framing members. This method requires a horizontal structural member (lintel) at the top of the wall to carry the roof loads to the posts. The panels are inserted beneath the lintel and between the posts.

With either of these systems, openings for windows and doors can be placed anywhere between posts.